

Claims

- [c1] A method of removing NO_x gases from a flue gas, the method comprising the steps of:
- contacting the flue gas with a scrubbing medium so that the scrubbing medium absorbs acidic gases from the flue gas to produce an acidic gas-containing solution and an intermediate flue gas;
 - reducing the temperature of the intermediate flue gas to convert nitric oxide to nitrogen dioxide;
 - absorbing the nitrogen dioxide from the intermediate flue gas to produce a nitrogen dioxide-containing solution and a scrubbed flue gas; and
 - reacting the nitrogen dioxide in the nitrogen dioxide-containing solution with ammonium hydroxide to produce ammonium nitrate.
- [c2] A method according to claim 1, wherein the step of absorbing the nitrogen dioxide from the intermediate flue gas comprises contacting the intermediate flue gas with a water-containing solution so that the water-containing solution absorbs the nitrogen dioxide from the intermediate flue gas to form the nitrogen dioxide-containing solution.
- [c3] A method according to claim 2, wherein the step of reacting the nitrogen dioxide in the nitrogen dioxide-containing solution comprises contacting the nitrogen dioxide-containing solution with an ammonia-containing solution containing the ammonium hydroxide.
- [c4] A method according to claim 2, wherein the scrubbing medium is an ammonium sulfate-containing solution containing ammonium hydroxide, and wherein the step of reacting the nitrogen dioxide in the nitrogen dioxide-containing solution comprises contacting the nitrogen dioxide-containing solution with the ammonium sulfate-containing solution.
- [c5] A method according to claim 1, wherein the step of absorbing the nitrogen dioxide from the intermediate flue gas comprises contacting the intermediate flue gas with an ammonia-containing solution so that the ammonia-containing solution absorbs the nitrogen dioxide from the intermediate flue gas to produce the nitrogen dioxide-containing solution.

- [c6] A method according to claim 1, wherein the scrubbing medium is an ammonium sulfate-containing solution.
- [c7] A method according to claim 6, wherein the step of absorbing the nitrogen dioxide from the intermediate flue gas comprises contacting the intermediate flue gas with the ammonium sulfate-containing solution so that the ammonium sulfate-containing solution absorbs the nitrogen dioxide from the intermediate flue gas to produce the nitrogen dioxide-containing solution.
- [c8] A method according to claim 1, further comprising the steps of accumulating the acidic gas-containing solution in a vessel, and introducing ammonia and oxygen into the vessel to react the acidic gases in the acidic gas-containing solution to produce ammonium sulfate.
- [c9] A method according to claim 8, further comprising the step of accumulating the nitrogen dioxide-containing solution in the vessel, where the ammonia introduced into the vessel forms the ammonium hydroxide that reacts with the nitrogen dioxide in the nitrogen dioxide-containing solution to produce ammonium nitrate.
- [c10] A method according to claim 1, further comprising the step of releasing the scrubbed flue gas to atmosphere.
- [c11] A method of removing nitric oxide gas and acidic gases from a flue gas, the method comprising the steps of:
 contacting the flue gas with an ammonium sulfate-containing scrubbing solution so that the scrubbing solution absorbs acidic gases from the flue gas to produce an acidic gas-containing solution and an intermediate flue gas;
 accumulating the acidic gas-containing solution in a vessel containing the ammonium sulfate-containing scrubbing solution;
 reducing the temperature of the intermediate flue gas to convert nitric oxide within the intermediate flue gas to nitrogen dioxide;
 contacting the intermediate flue gas with a water-containing scrubbing solution so that the water-containing scrubbing solution absorbs the nitrogen dioxide from the intermediate flue gas to produce a nitrogen dioxide-containing

solution and a scrubbed flue gas;
releasing the scrubbed flue gas to atmosphere;
accumulating the nitrogen dioxide-containing solution in the vessel containing the ammonium sulfate-containing scrubbing solution; and then
introducing ammonia and oxygen into the vessel to react the acidic gases in the acidic gas-containing solution to produce ammonium sulfate and to react the nitrogen dioxide in the nitrogen dioxide-containing solution to produce ammonium nitrate.

- [c12] A method according to claim 11, wherein during the step of contacting the intermediate flue gas with the water-containing scrubbing solution, the intermediate flue gas is also contacted with the ammonium sulfate-containing scrubbing solution, such that the nitrogen dioxide-containing solution also contains ammonium sulfate.
- [c13] A method according to claim 11, wherein the water-containing scrubbing solution used in the step of contacting the intermediate flue gas comprises the ammonium sulfate-containing scrubbing solution, such that the nitrogen dioxide-containing solution contains ammonium sulfate and water.
- [c14] A method according to claim 11, further comprising the steps of withdrawing a portion of the ammonium sulfate-containing scrubbing solution from the vessel and dewatering the portion of the ammonium sulfate-containing scrubbing solution to precipitate ammonium sulfate and ammonium nitrate.
- [c15] A flue gas scrubbing apparatus for removing NO_x gases from a flue gas, the flue gas scrubbing apparatus comprising:
means for contacting the flue gas with a scrubbing medium so that the scrubbing medium absorbs acidic gases from the flue gas to produce an acidic gas-containing solution and an intermediate flue gas;
means for reducing the temperature of the intermediate flue gas to convert nitric oxide to nitrogen dioxide;
means for absorbing the nitrogen dioxide from the intermediate flue gas to produce a nitrogen dioxide-containing solution and a scrubbed flue gas; and
means for reacting the nitrogen dioxide in the nitrogen dioxide-containing

solution with ammonium hydroxide to produce ammonium nitrate.

- [c16] A flue gas scrubbing apparatus according to claim 15, wherein the absorbing means comprises means for contacting the intermediate flue gas with a water-containing solution so that the water-containing solution absorbs the nitrogen dioxide from the intermediate flue gas to form the nitrogen dioxide-containing solution.
- [c17] A flue gas scrubbing apparatus according to claim 16, wherein the reacting means comprises means for contacting the nitrogen dioxide-containing solution with an ammonia-containing solution containing the ammonium hydroxide.
- [c18] A flue gas scrubbing apparatus according to claim 16, wherein the scrubbing medium is an ammonium sulfate-containing solution containing ammonium hydroxide, and wherein the reacting means comprises means for contacting the nitrogen dioxide-containing solution with the ammonium sulfate-containing solution.
- [c19] A flue gas scrubbing apparatus according to claim 15, wherein the absorbing means comprises means for contacting the intermediate flue gas with an ammonia-containing solution so that the ammonia-containing solution absorbs the nitrogen dioxide from the intermediate flue gas to produce the nitrogen dioxide-containing solution.
- [c20] A flue gas scrubbing apparatus according to claim 15, wherein the scrubbing medium is an ammonium sulfate-containing solution.
- [c21] A flue gas scrubbing apparatus according to claim 20, wherein the absorbing means comprises means for contacting the intermediate flue gas with the ammonium sulfate-containing solution so that the ammonium sulfate-containing solution absorbs the nitrogen dioxide from the intermediate flue gas to produce the nitrogen dioxide-containing solution.
- [c22] A flue gas scrubbing apparatus according to claim 15, further comprising a vessel in which the acidic gas-containing solution is accumulated, and means

for introducing ammonia and oxygen into the vessel to react the acidic gases in the acidic gas-containing solution to produce ammonium sulfate.

[c23] A flue gas scrubbing apparatus according to claim 22, wherein the nitrogen dioxide-containing solution is accumulated in the vessel, where the ammonia introduced into the vessel forms the ammonium hydroxide that reacts with the nitrogen dioxide in the nitrogen dioxide-containing solution to produce ammonium nitrate.

[c24] A flue gas scrubbing apparatus according to claim 15, further comprising means for releasing the scrubbed flue gas to atmosphere.

[c25] A flue gas scrubbing apparatus for removing nitric oxide gas and acidic gases from a flue gas, the flue gas scrubbing apparatus comprising:
means for contacting the flue gas with an ammonium sulfate-containing scrubbing solution so that the scrubbing solution absorbs acidic gases from the flue gas to produce an acidic gas-containing solution and an intermediate flue gas;
a vessel containing the ammonium sulfate-containing scrubbing solution and in which the acidic gas-containing solution is accumulated;
means for reducing the temperature of the intermediate flue gas to convert nitric oxide within the intermediate flue gas to nitrogen dioxide;
means for contacting the intermediate flue gas with a water-containing scrubbing solution so that the water-containing scrubbing solution absorbs the nitrogen dioxide from the intermediate flue gas to produce a nitrogen dioxide-containing solution and a scrubbed flue gas;
means for releasing the scrubbed flue gas to atmosphere;
means for accumulating the nitrogen dioxide-containing solution in the vessel containing the ammonium sulfate-containing scrubbing solution; and
means for introducing ammonia and oxygen into the vessel to react the acidic gases in the acidic gas-containing solution to produce ammonium sulfate and to react the nitrogen dioxide in the nitrogen dioxide-containing solution to produce ammonium nitrate.

[c26] A flue gas scrubbing apparatus according to claim 25, further comprising

means for contacting the intermediate flue gas with the ammonium sulfate-containing scrubbing solution, such that the nitrogen dioxide-containing solution also contains ammonium sulfate.

[c27] A flue gas scrubbing apparatus according to claim 25, wherein the water-containing scrubbing solution used in the step of contacting the intermediate flue gas comprises the ammonium sulfate-containing scrubbing solution, such that the nitrogen dioxide-containing solution contains ammonium sulfate and water.

[c28] A flue gas scrubbing apparatus according to claim 25, further comprising means for withdrawing a portion of the ammonium sulfate-containing scrubbing solution from vessel, and means for dewatering the portion of the ammonium sulfate-containing scrubbing solution to precipitate ammonium sulfate and ammonium nitrate.

Approved for Release by NSA on 09-08-2013 pursuant to E.O. 13526